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# Occlusive Impedance Plethysmography

## A Noninvasive Method of Diagnosis of Proximal Deep Vein Thrombosis

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*The purpose of this study was to assess and confirm the accuracy of impedance plethysmography (IPG) by the occlusive cuff method, in detecting proximal (popliteal, femoral and iliac) deep vein thrombosis in patients with symptomatic limbs. In 27 patients 30 consecutive limbs were studied with concurrent venography and IPG. The IPG result was normal in 9 of 9 limbs which were normal on venography, and abnormal in 15 of 16 limbs which showed venographic evidence of proximal deep vein thrombosis (DVT). An abnormal IPG strongly suggests proximal DVT (predictive value 0.88). A normal IPG virtually rules out proximal DVT (predictive value 1.0).*

THE PRESENCE of deep vein thrombosis (DVT) in the popliteal, femoral and iliac veins carries a high risk of pulmonary embolism.<sup>1-3</sup> At present, venography is the standard method of establishing the presence of deep vein thrombosis in the calf and thigh; however, it is far from ideal (Table 1). There are situations where venography is not feasible, and the procedure is not without risk. Perhaps the most serious consequence of its disadvantages is that physicians hesitate to order the test, and inaccurate clinical diagnoses are made. It has been repeatedly shown that clinical diagnosis of DVT is most unreliable.<sup>8</sup>

In the last several years, alternative methods have been developed that closely approximate the

accuracy of venography and, in addition, overcome some of its disadvantages. Of these, 125-I fibrinogen scanning provides accurate diagnosis of fresh calf vein thrombosis, while proximal thrombosis in the popliteal, femoral and iliac veins can be detected by impedance plethysmography.<sup>9,10</sup>

Impedance plethysmography or phlebography (IPG) was introduced and developed by Wheeler,<sup>11</sup> and in the last three years the occlusive cuff modification has been tested in several laboratories.<sup>7,12,13</sup> The accuracy of IPG has been variable, depending on details of the testing procedure, method of interpretation and the type of patient in whom the study is done. Accuracies of over 95 percent were achieved by Wheeler<sup>11</sup> and Hull<sup>7,10</sup> in the detection of symptomatic proximal deep vein thrombosis.

This method is based on considerations of venous physiology (Figure 1). Temporary occlusion of venous return by inflation of a thigh-cuff results in increase in venous volume of the calf;

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ABBREVIATIONS USED IN TEXT

DVT=deep vein thrombosis  
IPG=impedance plethysmography (phlebography)

TABLE 1.—*Limitations of Ascending Contrast Venography*

<i>Venography not feasible</i>
Unstable patients in intensive care
Possible pregnancy
Veins inaccessible for dye injection
Iodine allergy
<i>Complications</i>
Pain
Thrombophlebitis <sup>4</sup>
Allergic reactions
Renal damage in patients with myeloma or pre-existing renal disease. <sup>5</sup>
<i>Disadvantages</i>
Expensive
Difficult to repeat to follow disease
Iliac vein thrombosis may not be detected. <sup>6,7</sup>
Physicians hesitate to order the test

release of the cuff results in a rapid decrease in calf volume as blood drains into the proximal veins. If thrombosis is present in the veins proximal to the calf, initial calf volume increase is diminished and, more important, the rate of outflow of blood from the calf is decreased. These changes in calf blood volume can be detected by measuring changes in electrical resistance (impedance) of the calf.

The purpose of this paper is to report our experience with the IPG in detecting symptomatic DVT, using concurrent venography as the standard.

## Patients and Methods

### Patients

All patients referred for venography in the four months between January 26 and May 31, 1977, were studied. These included both medical and surgical inpatients and outpatients. Although not excluded, no patient had overt cardiac failure and no patient had hip surgical operations. All patients referred had clinical symptoms or signs suggestive of deep vein thrombosis.

### Venography

Ascending venography was done by the Stanford University Department of Radiology. The method of Rabinov and Paulin was used.<sup>6</sup>

### Impedance Phlebography

A model 200 Impedance Plethysmograph (Cintor) was used according to the method of Wheeler.<sup>11</sup> The total rise and three second fall were measured and scored on a graph provided by H. B. Wheeler, MD (written communication, 1977) (Figure 2). The graph was developed by computer analysis of 390 IPG-venogram correlations.<sup>14</sup> A gray area divides the normal and abnormal areas.

Normal test results were those that fell on the upper gray border and above. Nondiagnostic test findings were those that fell on the lower gray border and in the gray area. Abnormal test results were those that fell below the lower gray border.

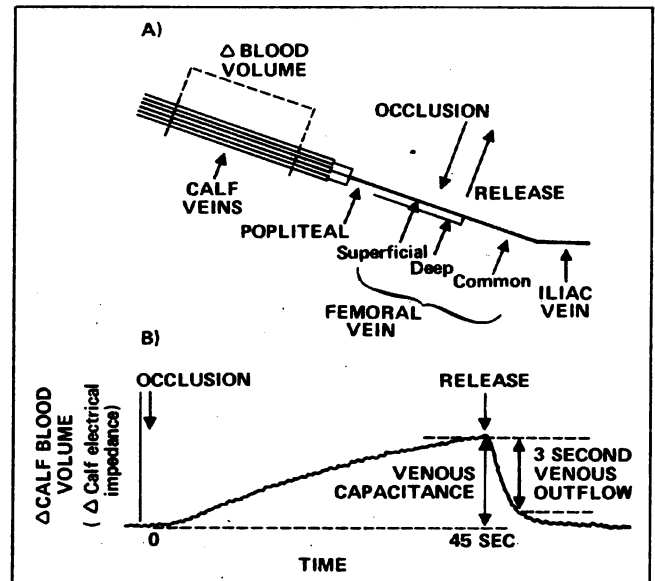


Figure 1.—Occlusive Impedance Phlebography (IPG). A. Schematic diagram of the deep veins of the lower extremities. B. IPG tracing showing calf blood volume changes following occlusion and release of a thigh tourniquet.

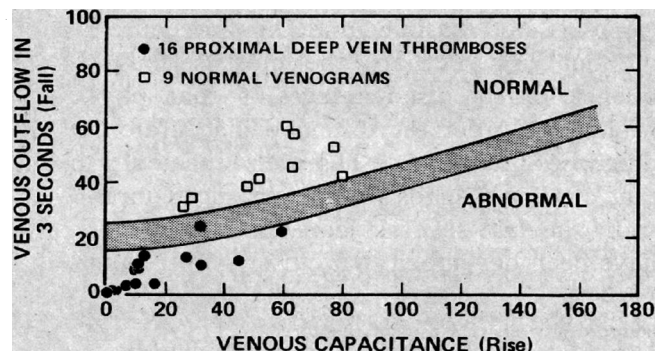


Figure 2.—Venous capacitance and 3-second outflow in 9 limbs with normal venograms and 16 limbs with thrombosis in the iliac, femoral or popliteal veins. (Graph provided by H. B. Wheeler, MD, Worcester, MA)

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TABLE 2.—Results of 30 IPG Venogram Correlations

IPG	Proximal DVT	Normal	Old DVT	Calf DVT
Abnormal .....	15	0	1	1
Normal .....	0	9	0	2
Nondiagnostic .....	1	0	0	1
	<hr/> 16	<hr/> 9	<hr/> 1	<hr/> 4

DVT = deep vein thrombosis  
IPG = impedance plethysmography

The most normal point of several measurements was used to represent the patient's IPG result.

If the initial result was abnormal, several maneuvers were tried before interpreting the test finding as abnormal: (1) If maximal filling during a 45 second cuff occlusion did not occur, a two-minute occlusion test run was done. (2) If the maximal filling was still small, the cuff was tightened. (3) If the outflow was slow, the cuff was loosened. (4) Different positions were tried. (5) Muscle relaxation was encouraged and medication given if the patient was in pain.

Venograms and IPG's were done and interpreted without knowledge of the result of the other, except in four patients, where the venogram result could have been inferred by person carrying out the IPG because it could be seen that the patients had been started on a regimen of heparin.

### Results

Between January 26, 1977, and May 31, 1977, venograms were done on 36 limbs for clinically suspected deep vein thrombosis. Venograms were normal in 15 (42 percent) and showed thrombosis in the deep veins in 21 (52 percent).

All limbs were studied by IPG except for six patients who were immediately discharged when venograms were found to be negative. In the 30 IPG's that were compared with venography, 28 were done within 48 hours of venography and two within the subsequent two days. Table 2 summarizes the results of the 30 IPG-venogram correlations.

#### Proximal DVT

Table 2 shows that IPG correctly identified 15 out of 16 limbs with proximal DVT, defined as thrombosis in the iliac, femoral or popliteal vein. The sensitivity was then 94 percent. The test correctly identified nine out of nine normal limbs,

a specificity of 100 percent. (For purposes of comparison, specificity is defined here, as in other series,<sup>7,11</sup> as number of test negatives/number of true negatives.)

In patients with less than two weeks of symptoms, 8/8 had abnormal IPG's. In those with symptoms longer than two weeks, 7/8 had abnormal IPG's.

#### Calf Vein DVT

Four limbs showed thrombosis of the calf veins only. IPG was abnormal in one patient, two had nondiagnostic IPG's and one was normal. There were two peroneal, two anterior tibial and two posterior tibial vein thrombi in four limbs.

#### Old DVT

One patient who had postphlebotic syndrome with ten years of chronic pain and swelling had an abnormal IPG. There were no acute symptoms. Venography showed evidence of old phlebitis with ragged vein walls, dilated superficial veins and nonvisualization of some deep veins.

The data were plotted on Wheeler's graph. If the graph of Hull and co-workers<sup>7</sup> was used, there was one false positive, but the overall accuracy remained 96 percent because the one nondiagnostic result would then be accurately diagnosed as abnormal.

### Discussion

Overall accuracy of IPG in the detection of proximal deep vein thrombosis was 96 percent in this small series and agrees with the accuracy of 95 percent to 98 percent reported in the two largest series.<sup>7,11</sup> We have confirmed that impedance phlebography done and interpreted as described is a sensitive and specific test for the diagnosis of symptomatic deep vein thrombosis of the popliteal, femoral and iliac veins. It should be noted that the accuracy is reported to be lower in asymptomatic limbs, and in patients who have had surgical operations on the hip.<sup>7</sup>

Moser and associates<sup>13</sup> reported that the IPG detected only 61 percent of DVT. Of the subgroup that had thigh thrombosis, 76 percent (13/17) were detected by IPG. The sensitivity was still lower than that of this and other series.<sup>7,11</sup> The authors attributed this to the presence of collaterals in the four IPG negative patients. The difference could also be one of methodology. The

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TABLE 3.—*Predictive Values of Impedance Plethysmography (IPG) in the Diagnosis of Proximal Deep Vein Thrombosis (DVT)*

	IPG	
	Abnormal	Normal
Proximal DVT ..... 15 (popliteal, femoral, iliac vein thrombi)	15	0
No proximal DVT ..... 2 (calf thrombi, no thrombi)	2	11
	17	11

Predictive value of abnormal IPG for proximal DVT:  $15/17=0.88$   
Predictive value of normal IPG for no proximal DVT:  $11/11=1.0$

cuff pressure used and the method of analysis were different from that used in the present and other series.<sup>7,11</sup>

### Test Interpretation

#### Positive IPG

As shown in Table 3, a properly carried out positive IPG with the patient relaxed is strong evidence for proximal DVT (predictive value 0.88). False positive rates (IPG abnormal/venogram normal) ranged from 1 percent to 4 percent in the largest series,<sup>7,10,11</sup> and were due to leg muscle tension, overt cardiac failure or pelvic tumor. In some institutions where there has been extensive experience with IPG, administration of heparin is started on the basis of a positive IPG result without venographic confirmation, provided there are no conditions that might result in a false positive test result.

#### Negative IPG

The false-negative rate (IPG normal/venogram abnormal) for proximal thrombosis is low in clinically abnormal limbs. None was missed in the present group (0/16) and only 1.7 percent (1/60) was missed in the larger series of Hull and associates.<sup>10</sup> A negative IPG result in a symptomatic leg then virtually rules out proximal deep vein thrombosis. The IPG, however, does not reliably detect small calf thrombi.<sup>7,10,11</sup> Symptomatic limbs with negative IPG results harbored 18 percent (2/11) and 16 percent (21/130) calf thrombi, respectively, in the present series and that of Hull and co-workers.<sup>10</sup>

The question then turns on the clinical significance of calf vein thrombi. When the thrombi are localized to the calf, the study of Kakkar suggests they rarely give rise to clinically significant pulmonary emboli; of 31 untreated calf thrombi in postoperative patients, none gave rise to clinically symptomatic pulmonary embolism.<sup>1</sup>

Recently, studies on a small group of postoperative patients suggest that thrombi limited to the calf may give rise to pulmonary emboli. However, these emboli were small and clinically silent.<sup>15</sup> The major clinical importance of calf thrombosis then is the potential to propagate proximally. Many studies have shown that approximately 20 percent propagate proximally if left untreated<sup>9</sup> and these patients would be at serious risk for symptomatic pulmonary embolism.<sup>1-3</sup> Since the risk of bleeding with heparin is approximately 10 percent to 20 percent,<sup>16,17</sup> routine anticoagulant treatment of calf thrombi may result in a morbidity that is greater than the potential benefit. If the burden of hospital admission and subsequent sodium warfarin administration is added, then the risk to benefit ratio is even higher. It may be safer to abstain from anticoagulation and monitor extension of thrombi in these patients. Wheeler has advocated following patients suspected of DVT with negative IPG's, every 48 to 72 hours, as long as they are at risk for venous thrombosis. Using this approach, symptomatic pulmonary embolism occurred only once in 286 patients (0.3 percent) with normal IPG tests.<sup>18</sup> However, others feel that calf thrombi should be sought and treated, because they may give rise to emboli<sup>15</sup> and because the safety of withholding therapy has not been clearly shown.<sup>10</sup>

#### Nondiagnostic IPG

Of the two limbs in the present series that had non-diagnostic IPG studies, one was shown to have a calf vein thrombus and the other had a nonocclusive proximal thrombus. In Wheeler's larger group,<sup>14</sup> results in this indeterminate area of the graph included limbs that were normal, had calf vein thrombi or proximal vein thrombi. Patients with nondiagnostic IPG results probably should be studied by venography.

#### Areas For Investigation

IPG has been proposed as a method of following the course of a thrombus while the patient is receiving anticoagulation therapy.<sup>19</sup> Its usefulness in decision-making regarding duration of anticoagulation therapy, while reasonable, remains to be tested.

Proximal deep vein thrombosis has been thought to be the major source of pulmonary emboli found at autopsy.<sup>2,3</sup> Proximal deep vein thrombosis then is likely to be present in many

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patients with pulmonary embolism, although symptoms of DVT may not be present. The actual incidence of DVT in pulmonary emboli has not been clearly shown in life because it requires carrying out venography and pulmonary angiography in sick, unstable patients. Recently, it has been reported that in patients with suspected pulmonary emboli, 90 percent of those with abnormal IPG had arteriogram-documented pulmonary embolism; conversely, of patients with negative IPG's, 90 percent had normal pulmonary arteriograms.<sup>19</sup> The potential predictive value of the IPG test result in patients with suspected pulmonary embolism warrants confirmation.

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## Common Errors in Lavage

ICE WATER LAVAGE does lessen peptic bleeding—or delays gastric emptying, which aids in evacuating the stomach; and it cleans the stomach for panendoscopy. . . . The common errors in lavage are the following: too small a lavage tube, too little volume or lavage force, too short a duration of lavage and too much suction force. . . . So it should be vigorous inflow and very gentle outflow.

—J. LOREN PITCHER, MD, *El Paso, Texas*

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